CIE Independent Peer Review Report

Eastern Bering Sea Crab and Groundfish Bottom Trawl Surveys

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Executive Summary

The ESB bottom trawl survey, with current design and sampling effort, is generally adequate for producing consistent and precise estimates of relative abundance for major fish and crab species over time, including walleye pollock, Pacific cod, yellowfin sole, northern rock sole, snow and tanner crabs. The bottom trawl survey generally covers soft-bottom habitats and will therefore not be suitable for fish and invertebrate species that favor hard-bottom substrate, such as red king crab. The very strong quality-control and quality assurance program implemented by AFSC to standardize trawl sampling protocols and trawl performance (warp length, wing-spread, net width, towing distance, etc.) minimize sources of errors in area-swept estimates due to changes in survey vessels over time. AFSC has excellent routines for data quality control, correction, and archiving, securing a database with high quality information. The EBS trawl survey is generally cost-effective for providing information that supports stock assessment and ecosystem forecast models used for stock assessment and harvest advice. The chosen systematic design with fixed stations is particularly suitable for estimating trends in abundance over time. However, some aspects of the survey design are ad-hoc, may be inefficient, and could introduce bias in key survey estimates. The rationale for the current stratification scheme is not well documented. Although no priority list of species exists, the stratification and doubling of the number of trawl stations in some strata may only be effective for one, or a limited number of species. Furthermore, the current method of allocating extra trawl stations in the upper corner of standard grid-cells can cause bias. It is recommended that any extra stations be allocated so that all stations in the strata have equal inclusion probabilities. Current analytical procedures follow those of a stratified random design although the EBS shelf bottom trawl survey uses a stratified systematic design. As a result, precision in current estimates of abundance is likely to be underestimated. Alternative variance estimators are suggested that could reduce bias in precision estimates.

Some possible ways of increasing the efficiency of the EBS bottom trawl survey for a fixed survey effort are proposed. In general, it is recommended that all aspects of the sub-sampling and data collections at each station be evaluated. In particular, the number of fish per length-class sampled for age should be evaluated to see how sample size at a station affects the precision in estimates of numbers at age through age-length keys. The effective sample size for estimating age is mostly driven by the number of stations sampled, and may be little affected if less fish are aged at each station. It appears that the field personnel at times are overloaded with too many tasks. The core survey objectives should have priority. Additional specials studies may require extra funding and expanded survey time. It is recommended that the towing time at each trawl station be reduced from 30-min to 15-min. This would reduce the need for sub-sampling of catches in addition to freeing time for other studies. Reduced towing time could be phased in over time by first taking 15-min and 30-min tows at a random set of stations, balanced across survey vessels, strata, and depth. It is also recommended that the costly re-sampling of red king crab in Bristol Bay be reconsidered. This re-sampling is costly, and contributes little to the overall survey objectives. Alternative optic survey methods

should be considered for red king crab, since this species favors hard bottom and is poorly covered by the bottom trawls survey which mostly covers soft bottom habitat.

1. Background

The eastern Bering Sea bottom trawl survey has been conducted by the Resource Assessment and Conservation Engineering Division of the Alaska Fisheries Science Center, National Marine Fisheries Service, since 1975, and annually since 1979. The EBS bottom surveys are conducted with chartered commercial trawlers (10 different vessels have been used over the years), with trawls stations selected across the survey area according to a stratified systematic design with a fixed start. The spatial coverage of the survey was varying from 1975-1981, and then held near constant since 1982. Each tow is conducted according to NMFS bottom trawl protocols established by the National Oceanic and Atmospheric Administration (Stauffer 2004), using a standardized otter trawl made in-house and maintained by AFSC. Towing time is approximately 0.5 h in duration at a speed of 3 knots.

The EBS bottom trawl survey provides data on the distribution, relative abundance, and biomass of groundfish, crab, and other benthic resources in the eastern Bering Sea. The survey supports stock assessment and ecosystem forecast models that form the basis for stock assessment and harvest advice of major fish and crab species, including walleye pollock, Pacific cod, yellowfin sole, northern rock sole, red king crab, and snow and tanner crabs. Auxiliary data are collected to support research that improves the understanding of life history of fish and invertebrate species and the ecological and physical factors affecting their distribution and abundance. Acoustic data from BT survey vessels are routinely collected along the entire cruise-track, and have been employed to estimate walleye pollock abundance (Honkalehto et al. 2011).

Since 1988, 376 standard stations have been included in the regular systematic EBS trawl survey, covering an area of 140,350 nmi^2 in depths ranging from 20 to 150 m. The survey is costly, and it is therefore important that all aspects of the survey be cost-effective, and that the survey estimates used as input to stock assessments be sufficiently accurate for management advice. The main purpose of the current CIE review was to evaluate if the survey is as informative for stock assessment as it needs to be.

2. Description of the Review Activities

A peer review meeting was held at the Alaska Fisheries Science Center in Seattle, Washington, on April 10-12, 2012. The meeting was chaired and facilitated by Dr. David Somerton in an organized and effective manner, and was conducted in a spirit of cooperation and teamwork. The CIE review panel consisted of Drs. Yong Chen, Norman Hall, and Jon Helge Vølstad. Presentations were made to the CIE review panel by Dr. David Somerton and the AFSC staff involved in the evaluation process, during which the CIE panel members asked questions. A tour of the AFSC net shed was organized for the panel on April 10, allowing us to inspect the standard bottom trawl used in the Eastern Bering Sea Crab and Groundfish Bottom Trawl Surveys.

Preparations in advance of the peer review meeting included a review of all background material and reports provided by the NMFS Project Contact Dr. David Somerton. The required reading material for this review was provided to the CIE review panel via ftp on March 24, 2012, and included: 1) Groundfish data report, 2) Crab data report, 3) General review of the EBS survey in Wakabayashi et al., and 4) Report chapter of the US Trawl Survey Standardization Protocols dealing with the EBS survey. The review preparation also included the reading of relevant peer review literature obtained through web-of-science and several general background reports provided by AFSC via ftp: 1) Crab stock assessment report, 2) Pollock stock assessment report, 3) Yellowfin sole stock assessment report, and 4) a list of literature by groundfish assessment staff on issues related to the trawl surveys (See Appendix 2 for details).

A series of very informative power-point presentations were given by Dr. David Somerton and his staff during the review meeting:

- David Somerton. CIE Review of the Bering Sea Shelf Bottom Trawl Survey.
- David Somerton. Experimental estimation of q (catchability).
- David Somerton. Presentations on the survey estimates and uncertainty relative to model assumptions and structure: introduction.
- Robert Foy. Crab Data Analysis: Eastern Bering Sea Bottom Trawl Survey.
- Ken Weinberg. Trawl survey standardization.
- Jim Ianelli. Eastern Bering Sea Pollock stock assessment.
- Stan Kotwicki. Improving walleye pollock assessment with acoustic data collected during bottom trawl surveys.
- Bob Lauth. Analytical methods, Groundfish. General.
- Bob Lauth. Data QA/QC Databases.
- Tom Wilderbuer. Adequacy of Bering Sea shelf survey for flatfish.
- Jack Turnock. Crab Length based stock assessments.

These power-point presentations complemented the documents provided by AFSC for the peer review, and allowed in-depth discussions on several aspects of the EBS survey.

3. Summary of Findings for each ToR

3.1. Evaluate the data collection operations and sampling design of the survey in term of their adequacy for producing consistent and precise estimates of relative abundance for the various fishes and invertebrates of concern.

The Eastern Bering Sea bottom trawl surveys survey aim to provide data for estimating the relative abundance (by length and for some species by age) over time for a wide range of crab and groundfish species. No priority list of species was provided for this CIE review, although the use of survey data in assessment of walleye pollock, yellowfin sole, and snow crab were in focus during the review meeting. Apparently there are no treaty obligations requiring a specific level of precision for estimates of relative abundance.

Clearly, the adequacy of the EBS bottom trawl survey in terms of accuracy (bias and precision) of abundance indices will depend on the spatial coverage and design of the survey, spatial variation (patchiness and area of occupancy) by species, habitat preferences, and behavior of the species that affects their availability to the trawl (e.g., vertical distribution in the water column).

The chosen systematic design with fixed stations is particularly suitable for estimating trends in abundance over time. Many studies have concluded that a systematic design with regularly spaced samples can be optimal for a variety of reasonable spatial correlation functions of the sampled populations (see Steven and Olsen 2004, and many references therein). The trawl survey provides precise estimates of relative abundance, with RSE = {SE/Mean} in yearly estimates typically being between 10% and 20% for rock sole, yellowfin sole, Alaska plaice, pacific cod, and walley pollock (particularly for 6+). Walleye Pollock of ages 1-3 are distributed mid-water and largely unavailable to the trawl. For the walleye pollock assessment, hence, additional acoustic data from midwater are needed since younger year classes are distributed higher in the water column (see, e.g., Honkalehto et al., 2011). During the review meeting, ongoing research at AFSC on the use of acoustic data from the chartered vessels (vessels of opportunity) was presented.

The very strong procedures for standardizing trawling operations and trawl performance employed in the EBS bottom trawl survey should largely control for vessel effects in the survey time series. The variable timing of the start and end-time of the survey could affect the estimates of abundance by size and sex for some species. Such effects are difficult to control for and may cause a variable and unknown bias in estimates.

The adequacy of the precision achieved by species depends on the assessment model and other data-sources, and is difficult to evaluate since no precision requirements were provided. The evaluation of the adequacy of the survey for stock assessments would ideally take into account the propagation of sampling errors in input data from multiple sources (e.g., catch-data, abundance indices from bottom trawl surveys, and acoustic surveys) to the assessments output results used for management advice. During the review meeting, the assessment scientists gave their opinion on the adequacy of the survey based on their experience and use of survey data in assessment modeling. They were generally satisfied with the EBS bottom trawl performance for the major fish and crab species. The standard survey trawl is particularly good for sampling the flatfish species, and the survey covers the main area of the flatfish distribution. The trawl has high and consistent catching efficiency for flatfish across age classes since these do not out-swim the trawl, do not go above the headrope or below the footrope on a consistent basis, and do not become less available with age. The survey supports full analytical stock assessment every year, and the assessment scientist finds very few inconsistencies in the data, good model fits, and precise survey estimates of relative abundance.

For species that occupy only a limited part of the survey area only a fraction of the survey stations may provide biological data, and hence the precision of abundance estimates may be low. The bottom trawl survey generally covers soft-bottom habitats and will therefore not be suitable for fish and invertebrate species that favors hard-bottom substrate, such as red king crab. The abundance indices for red king crab are very imprecise and likely to be very biased since this species occupies a minor portion of the total survey area, and favors hard bottom which may not be trawlable. Current bottom trawl sampling is therefore inadequate for stock assessment and advice for this species. Other sampling strategies that can cover hard-bottom habitats may be considered including optical methods like a video-sled.

AFSC has made extraordinary efforts to standardize survey trawl performance and adjust for fish availability to the survey trawl gear to secure consistent swept-area estimates of relative abundance over time for major fish and crab species. Trawl performance studies have included examinations of door and net spread, net height, and bottom contact and their influence on catch efficiency. Sub-sampling of catches and data collections at each trawl station is conduced according to a standardized protocol, and Quality Assurance/Quality Control (QA/QC) procedures include fish and shellfish reference collections and photo documentation.

AFSC has apparently conducted little research on the optimization of survey design, and estimates of precision are generally based on estimators for stratified random sampling. It is recommended that alternative methods for estimating precision (relative standard error, RSE) under systematic sampling be explored. The stratified two-dimensional systematic sampling employed in the standard EBS bottom trawl survey is likely to produce more precise estimates of mean abundance indices than a stratified random sample of trawl stations. The reason is that the systematic sample provides a uniform coverage within strata, with spacing of the trawl stations that eliminates nearby sample units which may show a high degree of positive correlation (spatial autocorrelation). However, a drawback of systematic sampling is that no direct design-based estimator of the variance is available since this design is equivalent of a cluster-survey of sample size 1 (See section 3.2). An additional advantage of fixed stations is that bias caused by the variation in catching efficiency of the trawl by depth is held constant over time.

Some aspects of the survey design employed for the bottom trawl survey may introduce bias in the abundance estimates (see section 3.2):

- The method of allocating extra trawl stations in the upper corner of the systematic grid in some strata is likely to introduce bias (all other parts of the grid-cell have zero inclusion probability). A better practice would be to allocate the additional stations in these strata randomly, or alternatively use a finer grid with one station in each cell at the mid-point, or random. This would improve precision, eliminate bias, and support improved estimates of variance for the estimated means.

- The practice of extra sampling around hot-spot stations for many years starting in the mid-1990s is an ad-hoc adaptive method that may introduce substantial bias in mean abundance. Each station producing ≥ 100 legal-sized male red king or Tanner crab was considered a "hot spot". At each hot spot, multiple tows were made within the station area, and all crab species caught in tows were sampled identical to the standard survey tow protocol. Abundance estimates for these species should be revised to reduce the bias introduced by hot-spot sampling. The hot-spot sampling was discontinued in 2011.

The survey coverage in the earlier part of the survey time series has varied. A simple exercise to evaluate the importance of incomplete coverage for main species would be to start with a time series from the consistent set of systematic stations sampled in all years, and then sequentially add survey areas that are sampled less frequently and look at effects on the relative abundance estimates. If data are imputed for missed areas during years of incomplete coverage, the uncertainty in the imputations could be taken into account for overall uncertainty.

3.2. Evaluate the analytical methodology.

The review meeting and presentations focused on estimates of abundance indices by size and age for a limited number of species.

The AFSC treats the data from the EBS bottom trawl survey as if the design is stratified at random. The resulting variance estimates of the mean abundance indices are likely to be biased upwards, and therefore overestimate the sample size needed to achieve a desired level of precision. The systematic design will outperform all alternative schemes for certain underlying spatial autocorrelation structure in abundance (see, e.g., Dunn and Harrison 1993, and references therein). Dunn and Harrison (1993) show that a post-stratification of the systematic sample (e.g., pooling of 2 grid-cells to yield post strata with two samples each), and the use of a variance estimator that treats the sample as a stratified random sample, may reduce the bias in the variance estimates as compared to treating the survey as a stratified random, based on original strata boundaries. They argue that although both methods of estimating sampling error for a systematic survey are likely to provide an over-estimate of the true sampling error, the post hoc stratification is the better of the two. For the EBS survey an alternative method for walleye pollock may be to use a model-based estimator, and take advantage of the acoustic data to get estimates of the autocorrelation structure for different lags. Bartolucci and Montanari (2006) present several unbiased estimators of the variance of the systematic sample mean under mild conditions.

The proposed use of kriging to estimate the variance of the sample mean is not likely to work well for the current systematic survey design. Kriging is generally based on empirical variograms, or estimates of average squared differences of data taken at sites lagged the same distance apart. The baseline systematic sampling employed in the EBS survey maximizes the distance between stations in each stratum, and therefore little or no information (apart from acoustic data and some repeat hauls) is available to model the spatial correlation at shorter lags than the spacing between regular stations. Future surveys could include additional stations that are optimized towards the estimation of variograms for use in kriging (Mueller and Zimmermann Block-bootstrapping 1999).

The hot-spot sampling for red king crab will introduce a bias if all the extra samples are included in the abundance estimator with equal weights (Thompson and Seber, 1996). This bias may be removed by applying the Rao–Blackwell estimator (Thompson and Seber, 1996). Harbitz and Pennington (2009) provide an example where they removed bias caused by adaptively taking extra observations in high density strata in an acoustic survey.

For the walleye pollock, the practice of estimating an age-length key for the entire survey area, and not by strata, may introduce bias due to differences in growth from south to north. It appears that all stations are given equal weight in the age-length keys. Hence, strata with higher sample density will contribute more than strata with standard sample density. I recommend that some check be done to verify if the bias is of concern.

3.3. Evaluate the procedures used for data quality control and archiving.

AFSC has excellent routines for data quality control, correction, and archiving. The current system has evolved over time. The data archiving and quality control procedures for the RACEBASE database have gone through major updates since the ESB survey was standardized in 1982. From 1982 to 2006 the data editing occurred outside the database framework before being uploaded and data editing was not audited. For these years, the database store combined observational level and summarized data; sub-sampled catches were extrapolated to totals at several levels. Since 2007 the observational level data are entered directly into the database at sea (goal) or shortly after the cruise is completed. Biological data are archived at the sampling level, and include meta-data on sampling fractions for sub-sampled hauls. Numbers at age by haul is calculated outside the database, and allows for the evaluation of sample errors at several stages. The database includes metadata on the survey design and quality of hauls. Extensive net mensuration and environmental data collected during the survey are archived. Data editing is conducted within the Oracle database framework, and is audited. Changes in data, and by whom, is documented. After editing, data are finalized and archived. In my opinion, the QA/QC framework currently employed by AFSC for the EBS survey is state-of-the art, and secures high quality data.

The quality of taxonomic data is secured by a systematics laboratory (with three taxonomists) that maintains a voucher database, and deposits specimens at University of Washington, Smithsonian, and other places. QA/QC control checks of the species identification conducted in the field are also done through photographs, specimen vouchers, and tissue samples. A very strong feature is that the database includes metadata on the quality of taxonomic identifications over the years. This information can be used to decide on the taxonomic level that can be supported by the data when doing time-series analysis. This is important when using time-series of data to study biodiversity. The improved taxonomic identification has also allowed the monitoring of more fish by species. The quality of current taxonomic data is excellent.

3.4. Evaluate the research approaches to evaluate gear performance and estimate survey catchability.

AFSC conducts world-class research and employs state-of-the art methods for evaluating and correcting for bottom trawl performance. They have impressive protocols for quality assurance and quality control. The decision to abandon the correction for vessel effects in the survey time series is based on sound scientific arguments. The research to estimate survey catchability combines strong expertise in bottom trawl and acoustic survey methods. The area-swept estimates may even be further improved in the future based on AFSCs strong research on the effects of gear performance on catchability. This would require that key data on gear performance are routinely available in a form that can be used in the area-swept estimates. Over time, it may be possible to correct for catching efficiency of the gear across major species to achieve approximately absolute abundance estimates.

3.5. Evaluate the collection of ancillary biological and environmental data in support of an ecosystem approach to fisheries management.

The information on ancillary biological and environmental data collections provided for this review does not allow for an in-depth evaluation of the design, sample collection protocols, etc. However, based on the presentations at the review meeting it is apparent that the field staff may be over-loaded with work at each station. It is important that AFSC make a priority list to secure high quality data collections to support the main goals of the EBS survey. Hence, the time spent on each station should not exceed a threshold that would require a reduction in the total number of survey stations in the standard fixed grid. It is important that a thorough evaluation of sample sizes required for each species and objective at each station be done. The EBS bottom trawl survey now collects data for a large number of special research projects according to a list of priority, but the total time of these projects may threaten the core EBS trawl survey program. Data for special projects are collected on infaunal macroinvertebrate species, plankton, sea-birds including short-tailed albatross sightings (endangered). Stomach sampling is conducted to support food-web analysis, etc. For any of these data collections it is important to be cost-effective, and avoid over-sampling (see Bogstad et al. 1995). Stomach data incorporated into assessment models, such as the predation-mortality incorporated in year-class strength of Pollock, should have high priority. Bottom habitat sampling combined with acoustic bottom sediment mapping (see Diaz, et al. 2004) can yield important data on essential fish habitat.

3.6. Evaluate whether the survey data could be collected more cost effectively.

The fixed systematic design is well suited for estimating trends in relative abundance over time. An alternative design such as stratified random sampling with partial replacement (Cochran 1977), where for example a random sub-set of 50% of the stations where repeated from one year to the next, would provide a balance between status and trend. However, the long time series for the current fixed systematic design suggest that the baseline set of fixed stations be continued. With exception for some strata with higher density of stations, the current design provides a uniform coverage of stations across the survey area. This is a reasonable approach when no priority is given to specific species. It is likely that the survey could be optimized to yield higher precision for specific species for the same survey effort, based on information on the spatial distribution of the species over time. It is recommended that stratification and the allocation of extra sampling effort above the baseline fixed stations, be based on a priority list of species. Stevens and Olsen (2004) provide methods for spatially balanced sampling that would be more suitable for covering the many strata in the EBS surveys.

I here present some changes in survey sampling procedures that may improve the efficiency of the EBS survey overall:

- A change from 30-min tows to 15-min tows would:
    - Reduce overall towing time, freeing time for more stations for other studies, or to increase precision for fixed survey effort. Alternatively this would reduce overall survey time by ~ 100 hours
    - Reduce the catch sizes at each station and, hence, reduce the need for sub-sampling which can cause bias
    - Reduce wear-and-tear on the net

- It is recommended that 15-min tows be phased in by first taking 15-min and 30-min tows at a random set of stations, balanced across survey vessels, strata, and depth. By using this approach, bias corrections for end-of-tow effects when reducing from 30-min to 15-min hauls could be evaluated and adjusted for if necessary. With the sophisticated gear performance monitoring conducted by AFSC, it should be possible to standardize the area-swept of 15 minutes so that it is comparable to estimates from

30-min tows. See Godø et al. (1990), and Pennington and Vølstad (1991, 1994) for some studies on tow duration.

- Change the method for selecting extra stations in strata with increased sampling density. The current approach to sample extra stations in the upper corner of grid-cells is biased. A better approach would be to create a higher density grid for these strata, or alternatively allocate the extra stations randomly, one in each grid cell.

- Explore alternative stratification and allocation schemes that are optimized towards some high priority species, using data from the time series of surveys.

- Use historic data to evaluate effect of re-stratification, re-allocation, and changes in survey coverage (e.g., dropping stations at edges with consistent low catch to save travel time)

- Reconsider the costly re-sampling of red King crab, which contributes little to the overall survey objectives. This effort takes approximately 8 vessels days that could be used for other studies. One approach could be to reduce the number of stations in Bristol Bay that are re-sampled, or re-sample every 3rd year since there appears to be little yearly variation in the estimates of the proportion that is ovigourous (around 90% have been mated) based on the re-sampled stations. It should be noted that red King crab only occurs in a small part of the survey area, and favors hard bottom that cannot be effectively sampled by the standard bottom trawl. Hence, alternative survey methods would be needed to achieve reliable estimates of abundance for this species.

- Use freed time for towing time reduction and reduced re-sampling of red King crab for gear q studies.

- Solicit funds from other sources to cover special studies that are outside the core objectives of the EBS bottom trawl survey.

- Take replicate sub-samples of large catches (for every k^{th} catch) and store the sub-sample data separately. Such embedded experiments would build up data over time to evaluate bias and required level of sub-sampling. The experiment could also be used to evaluate effects of smaller sub-samples of catches. Smaller sub-samples would reduce work-load at stations with large catches.

- In general, it is recommended that all aspects of the sub-sampling and data collections at each station be evaluated. In particular, the number of fish per length-class sampled for age should be evaluated to see how sample size at a station affects the precision in estimates of numbers at age through age-length keys. The effective sample size for estimating age is mostly driven by the number of stations sampled, and may be little affected if less fish are aged at each station.

3.7. Provide recommendations for further improvements

For age- samples, use simulation studies to assess how many otholiths per length class needs to be read for age. Also, evaluate if age collections in the field (number of samples by size class) could be reduced. This evaluation may be done through embedded experiments where sub-sampling for age is investigated.

Extra stations taken in addition to a uniform systematic grid of stations could only focus on a priority list of species. If only a few species are subject to catch sampling at these stations, the time for sampling would be greatly reduced, allowing for more stations that could improve precision for priority species.

The EBS survey could use any time-savings to improve on bottom habitat sampling (Diaz et al. 2006) in the survey area. This would be cost-effective since the boats cover the network of stations already. The extra hour saved by day by taking 15 min tows, for example, could be used to collect habitat data. Such data could provide information over time for more effective stratification based on habitat preferences of important target species.

4. Conclusions and Recommendations

The EBS bottom trawl survey with current design and sampling effort is generally adequate for producing consistent and precise estimates of relative abundance for major fish and crab species over time, including walleye pollock, Pacific cod, yellowfin sole, northern rock sole, and snow and tanner crabs. It is important that a priority list of species to focus on for a fixed survey cost be established. To achieve reliable abundance estimates for species which favors hard bottom habitats, such as red King crab, the survey would need to be complemented with alternative methods such as video-sleds. However, this would add cost, and would contribute little or no information for other species.

The chosen systematic design with fixed stations is particularly suitable for estimating trends in abundance over time. The current estimates of variance in mean abundance are based on estimators for stratified random sampling. It is recommended that alternative estimators be explored since current estimates are likely to be upwardly biased.

AFSC conducts world-class research and employs state-of-the art methods for evaluating and correcting for bottom trawl performance. Quality assurance and quality control procedures from the monitoring of trawl performance, sampling protocols, taxonomic identification, and data storage is of very high quality.

The EBS bottom trawl survey is generally conduced in a cost-effective way. However, some aspects of the stratification and allocation of stations to strata are ad-hoc and could result in bias. Alternative approaches are proposed that would eliminate this bias. Some possible improvements in the survey design and methods of analysis are proposed here. It is recommended that AFSC explore alternative stratification and sample allocation schemes that are optimized towards some high priority species, using data from the time series of surveys. A reduction of towing time at each station to 15-mins is recommended. This would reduce the need for sub-sampling and free up time for other studies, such as experiments to estimate catchability q, or habitat studies. It is recommended that 15-min tows be introduced for a stratified random half-set of stations initially. This would allow the evaluation and correction of possible differences in area-swept estimates as compared to 30-min tows. The costly re-sampling of red king crab, which contributes little to the overall survey objectives, should be re-considered. One option could be to reduce the number of stations in Bristol Bay that are re-sampled, or re-sample every 3rd year. Historic data suggest little yearly variation in the estimates of the proportion of red King crab females that is ovigourous and, hence, interpolation may be used for years in between.

Finally, some comments on the format of the review. The peer review process was very well organized, and the presentations and discussions at the peer review meeting were invaluable for understanding the complexity of the groundfish survey program. For a review of this complexity, with a wide range of topics, it would perhaps be more effective if the CIE peer review panel wrote a joint report. This would allow each expert to focus more on the topics within their core expertise for the given time for the review, while background information could be covered only once.

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Appendix 2: A copy of the CIE Statement of Work

Statement of Work

External Independent Peer Review by the Center for Independent Experts

Eastern Bering Sea Crab and Groundfish Bottom Trawl Surveys

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The Alaska Fisheries Science Center (AFSC) requests a Center of Independent Experts (CIE) review of the eastern Bering Sea crab and groundfish bottom trawl surveys. The data from this survey are used in more than 25 stock assessments conducted by the AFSC as well as the State of Alaska and the International Pacific Halibut Commission. Although all AFSC bottom trawl surveys, as well as those conduct by other NMFS science centers, were examined closely during the development of the NOAA Bottom Trawl Protocols in 2004, the AFSC surveys have never been formally reviewed by a CIE panel. The AFSC has conducted considerable research on factors affecting trawl performance and catchability and their impacts on resulting survey estimates of distribution and abundance. However, in recent years the trawl and survey performance and results of this multi-species survey have come under scrutiny by industry, particularly with respect to Bering Sea red king crab, snow crab, and Pacific cod. Considering the importance of the data produced by the Bering Sea bottom trawl surveys, a CIE review in 2012 would be timely and beneficial. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of stock assessment, including population dynamics, survey design and methodology, and statistical analysis. It is not expected that each of the three reviewers have all of these specialized areas of expertise, rather that at least one of the three reviewers should be knowledgeable in each of these areas. Reviewers should also have experience conducting stock assessments for fisheries management. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Seattle, Washington tentatively during April 10-12, 2012.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later than the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Other Tasks – Contribution to Summary Report: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate in the panel review meeting in Seattle, Washington during April 10-12, 2012.
3) In Seattle, Washington during April 10-12, 2012 as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than April 26, 2012, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and CIE Regional Coordinator, via email to David Die ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

March 6, 2012	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
March 27, 2012	NMFS Project Contact sends the CIE Reviewers the pre-review documents
April 10-12, 2012	Each reviewer participates and conducts an independent peer review during the panel review meeting
April 26, 2012	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
May 10, 2012	CIE submits CIE independent peer review reports to the COTR
May 17, 2012	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall be completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,

(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Key Personnel:

David Somerton, NMFS Project Contact
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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Tentative Terms of Reference for the Peer Review

Eastern Bering Sea Crab and Groundfish Bottom Trawl Surveys

1. *Evaluate the data collection operations and sampling design of the survey in term of their adequacy for producing consistent and precise estimates of relative abundance for the various fishes and invertebrates of concern.*
2. *Evaluate the analytical methodology.*
3. *Evaluate the procedures used for data quality control and archiving.*
4. *Evaluate the research approaches to evaluate gear performance and estimate survey catchability.*
5. *Evaluate the collection of ancillary biological and environmental data in support of an ecosystem approach to fisheries management.*
6. *Evaluate whether the survey data could be collected more cost effectively.*
7. *Provide recommendations for further improvements*

Note – CIE reviewers typically address scientific subjects, hence ToRs usually do not involve CIE reviewers with regulatory and management issues unless this expertise is specifically requested in the SoW.

Annex 3: Tentative Agenda

CIE Review of the Eastern Bering Sea Crab and Groundfish Bottom Trawl Surveys
Alaska Fisheries Science Center
7600 Sand Point Way NE, Seattle, WA 98115
Building 4; Room 2076 (April 10-12, 2012)

Review panel chair: David Somerton, david.somerton@noaa.gov

Survey group leaders: Robert Lauth, bob.lauth@noaa.gov (groundfish) and Robert Foy, robert.foy@noaa.gov (crab)

Security and check-in: Ron Erickson, ron.erickson@noaa.gov
Sessions will run from 9 a.m. to 5 p.m. each day, with time for lunch and morning and afternoon breaks.
Discussion will be open to everyone, with priority given to the panel, presenters, and survey group leaders.

Tuesday, April 10th

0900 Welcome and Introductions. The EBS environment and commercial fisheries (*Somerton*)

0930 The EBS survey (*Lauth & Foy*)

History of the EBS survey, current sampling design including the use of charter vessels. Description of the trawl pre- and post- 1982. Wheelhouse activities and catch processing procedures – i.e. how we do a tow. Area swept estimation – how we do it and why.

10:30 Break

11:00 The EBS survey (continued**;** *Lauth & Foy*)

11:30 Database, data editing and QA (*Vijgen*)

12:00 Lunch

13:00 Survey standardization (*Weinberg*)

14:00 Tour of net shed

1530 Analytic methodologies used for the estimation of relative abundance (*Lauth & Foy*)
Area swept estimation: new approaches. Biomass and variance calculation.
The fishing power correction. Post hoc sampling for crab – hot spots and retows.

Wednesday, April 11th

0900 Q research - demersal fish and crabs (*Somerton*)

Snow crab selectivity. Escapement and herding of flatfish. Vertical availability of Pcod. Light and vertical distribution

10:15 Break

10:30 Use of acoustics on the EBS survey (*Kotwicki*)

AVO project (collect acoustics for others). Acoustic and bottom trawl blind zones (combining acoustic and bottom trawl survey for pollock). Using acoustics to estimate Pollock between stations to improve biomass estimate.

12:00 Lunch

1300 Presentations on the survey estimates and uncertainty relative to model assumptions and structure: introduction (*Somerton*)

13:15 Yellowfin sole (Wilderbuer)

13:45 Pollock (Ianelli)

14:15 Snow crab (*Turnock*)

14:45 Break

15:15 Discussion between CIE committee and survey scientists

Thursday, April 12th

0900 -1200 Presentations on the survey estimates and uncertainty relative to model assumptions and structure (continued)

noon -1300 Lunch

1300 -1700 Discussion and wrap-up

Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

David Somerton (Chair)

Jon Vølstad, Head of Research Group on Fisheries Dynamics, Institute of Marine Research, Bergen, Norway.

Yong Chen, Professor, School of Marine Sciences, University of Maine, Orono, ME.

Norman Hall, Professor, Centre for Fish and Fisheries Research, Murdoch University, Australia.